SYSTEM ANALYSIS OF A LUG BY MOIRE FRINGE METHOD

Aslam*, R.Kumar**, G.S.Sekhon and M.S. Palanichamy*
*Dept. of Civil Engg. Mepco Schlenk Engineering College,
Sivakasi -626 005, Tamil Nadu, India
**Indian Institute of Technology, Delhi, New Delhi - 110 016 India

ABSTRACT
A set of experimental procedures, based upon the moire fringe method has been used for measuring elasto-plastic strains in a lug. Results of experiments conducted on aluminium specimens have been presented and discussed. It is found that moire fringe method gives reliable measurement of strain in lug.

INTRODUCTION
In aircraft, lug type joints are frequently used in connecting structural elements. The basic configuration of lug is a hole fitted with a pin as shown in Fig.1. The lug is normally connected by means of single bolt or pin, creating a simple joint that is easy to assemble or disassemble. Since clamping of joint is normally not allowed, the lug can act as a pivot. In certain situations, lugs are critical components since consequences of their failure are severe.

Fig. 1 : Typical Lug Configurations
Several analytical numerical analyses of stress distribution in a lug[1-4] have been reported in the published literature. It is usually considered appropriate to test their validity carrying out experimentally. Frocht and Hill[5] use model material and photoelasticity to study the effect of geometric changes on the stress distribution in a lug. Schijve and Hocymooker [6], following the procedure developed by James and Anderson [7], obtained empirical stress intensity factor relations from the crack growth rate data of through the thickness cracks under constant amplitude loading. Heywood [8] has studied the effect of friction at the pin-lug interference-fit duralium pin was tested. He found that the influence of pin clearance on the stress concentration in the lug is rather anomalous. Catright and Ratcliffe [9] carried out experiments o an Instron machine in order to determine the strain energy release rate in the case of two equal radial crack emanating from a central hole in a finite width strip. Published studies on strain measurement in a lug by moire fringe method are scarce. The present study deals with an experimental study of strain distribution in a lug using the moire fringe method.

EXPERIMENTAL SETUP

The experimental setup is shown in Fig. 2. The main components of the experimental work were the preparation of specimens, reproduction of gratings in the specimens, design and fabrication of a loading rig, conducting tests, recording fringe patterns and calculation of strain components Aluminium lug specimens were made. The specimens were loaded very slowly to a maximum load on Instron Fig. 2. The applied load and displacements are recorded at every step. Moire fringes are produced when a master grating is superimposed on a strain grating. The initial fringe pattern is formed by superimposing a master with a mismatch on the deformed strain grating Fig. 4 (a & b). The final pattern is obtained similarly after the specimen is loaded upto a desired level Fig. 4 (c & d).
LOADING RING

A loading rig was designed and fabricated to transmit an axial load on to the specimen. The rig consisted of an upper and lower connector. Two identical samples of the lug are assembled to the above two connectors by means of a bolt and a pin as shown in Fig. 3. The nominal diameter of the pin was equal to the hole diameter. Care was taken to machine the pin as to produce a snug (or push) fit between the pin and the hole. The mating surfaces of the pin and the ligament were made smooth. The top end of the upper connector and the lower end of the lower connector can be gripped in an Instron machine. The applied load was continuously recorded. The loading was gradually increased from elastic into the elasto-plastic range until the desired load was reached at which point, further loading was stopped.
Fig. 3: Loading Ring

c) u-moire for loaded specimen
d) v-moire for loaded specimen

Fig. 4: Photographs of u-moire and v-moire of unloaded and loaded specimen
RESULTS AND DISCUSSION

The specimen having the following dimensions: L = 200 mm, W = 75 mm, D = 25 mm, H = 150 mm. The specimen was loaded in elasto-plastic range. For numerical modeling its strain-hardening parameter \( a \) (given below) is also required. The thickness of the lug was taken to be 12.5 mm. Uniaxial tensile tests were performed on specimens prepared from the lug samples at room temperature with the aim of generating data to fit the following constitutive relations.

\[
\bar{\sigma} = \sigma_0 + a \bar{\varepsilon}
\]

Where \( \sigma, \varepsilon \) and \( a \) are flow stress in uniaxial tension, normal strain in the axial direction and strain hardening parameter respectively.

Analysis of the tensile test data on aluminium specimens yielded the following values of the different material parameters

\[
\sigma_0 = 56.0 \text{ N/mm}^2, \ a = 39.2 \text{ N/mm}^2
\]

The points lying on the horizontal section ABCE (Fig. 1) are very significant from the point of view of analysts, since the largest magnitudes of \( \varepsilon_x, \varepsilon_y \) and \( \varepsilon_{xy} \) are expected by using to occur there. The distance = BP of any point P along AB was non-dimensional by using the following relation:

\[
\xi^* = \frac{\xi}{AB}
\]

\[
\text{Swhere } AB = \frac{W - D}{z}
\]

STRAIN DISTRIBUTION

The load on each specimen assembled in the loading rig was equal to 15000 N. It was found to be sufficient in producing elasto-plastic strain in parts of lug specimen. Fig. 5 shows the variation of the normal strain \( \varepsilon_x \) with non-dimensionalized \( \xi^* \) on the horizontal section through the hole centre. \( \varepsilon_x \) is found to be...
negative over whole of the section. Its magnitude is largest at the hole boundary but tends to decrease sharply. Beyond $\xi^* = 0.35$, the magnitude of $\varepsilon_x$ remains more or less constant. Variation of $\varepsilon_y$ with $\xi^*$ is shown in Fig. 6. It is found that the normal strain is tensile over whole of the section AB. Its magnitude is also maximum near the hole boundary decreases initially sharply with decrease in $\xi^*$ upto $\xi^*$ approximately equal to 0.3. Thereafter it varies gradually with increase in $\xi^*$ towards the outer boundary A. Fig. 7 shows that the variation of the shear strain $\varepsilon_{xy}$ with $\xi^*$ is substantially similar to that of $\varepsilon_y$.

![Graph](Fig.5 Variation of $\varepsilon_x$ with non-dimensionalized horizontal distance $\xi^*$)

![Graph](Fig.6 Variation of $\varepsilon_x$ with non-dimensionalized horizontal distance $\xi^*$)
VALIDATION OF NUMERICAL MODEL

To check the validity of the finite element model, we analyse the specimens experimentally using the moire fringe method. The lug specimens were loaded into the elasto-plastic range.

Fig. 7 Variation of $\varepsilon_{xy}$ with non-dimensionalized horizontal distance $\xi^*$ corresponding to pin displacement of 5.0 mm

Fig. 8 Variation of $\varepsilon_{xy}$ with non-dimensionalized horizontal distance $\xi^*$ corresponding to pin displacement of 5.0 mm
Moire fringe pattern were recorded corresponding to pin displacement of 5mm, and components of strain calculated at the selected points of the aluminium lug was also simulated with the help of the program FEM2D [1]. The computed and measured distributions of strain components were plotted and compared Figs. 8 to 10.

Fig. 9: Variation of $\varepsilon_{xy}$ with non-dimensionalized horizontal distance $c^*$ corresponding to pin displacement of 5.0 mm

Fig. 10: Variation of $\varepsilon_{xy}$ with non-dimensionalized horizontal distance $c^*$ corresponding to pin displacement of 5.0 mm
CONCLUSION

The mismatch technique of moire fringe method has been successfully applied for measurement of strain in lug specimens. A rig for loading the specimens in an Instron testing machine has been designed and fabricated. A series of experiments were conducted on specimens of a round-ended lug. The fringe patterns corresponding to u-moire and v-moire were photographed in each case. The distinctive character of strain distributions in the elasto-plastic deformation is depicted. The measured strains used to test the validity of the proposed finite element model of the lug.

REFERENCE


